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ABSTRACT

The purpose of this study was to investigate the differential effects on low and high verbal students of verbatim study questions adjunct to a text describing science concepts. The sample consisted of 217 eighth grade students enrolled in twelve Calgary (Alberta, Canada) schools. Materials developed for the study included an introduction to the experiment, a textual description of five fossil categories (ammonites, brachiopods, gastropods, pelecypods, and trilobites), 20 study questions, and a placebo passage for the control group. Students were administered a verbal ability test prior to the presentation of the instructional treatments. Subsequently, the students were randomly assigned to one of three treatment groups: (1) text plus 20 study questions, (2) text plus no study questions, and (3) placebo passage. Later the students were administered an achievement posttest consisting of a visual concept test requiring the students to identify 40 fossil specimens presented in a stratified random fashion. It was found that students who were low verbal performers and who were provided with the text and no study questions scored significantly higher on the posttest than did those low verbal learners who were provided with the text and study questions. Linear regression analysis, using the verbal ability test scores (predictive variable) and the posttest scores (dependent variable) substantiated an ATI-ordinal interaction hypothesis. In addition, the text-plus-20-questions group substantially outperformed the control group. The results of the study suggested that verbatim study questions adjunct to a science text constituted a dysfunctional instructional support system, particularly when given to lower verbal students. In contrast, higher verbal students circumvented or were unaffected by such questions. (Author/SLH)

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Differential Effects of Science Study Questions

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Questions adjunct to textual materials have been entensively investigated in programmed and mathemagenic learning studies (Faw and Waller, 1976; Holliday, 1977; Wilson and Koran, 1976). In review, results from programmed instructional experiments in science (see Cowan, 1967; Owen, Hall, Anderson and Smert, 1965; Roebuck, 1976) and in other subjects suggested that low ability students were more likely helped by questions placed throughout a text (Snow, 1974). Rothkopf (1970) extended this work under the rubric of mathemagenic learning theory and investigated the specific (intentional) and general (incidental) facilitative effects of presenting pre- and postquestions adjunct to segments of textual passages. Here, specific effects were measured in the posttest using the inserted questions themselves, while general effects were measured using posttest items independent of the inserted questions. Generally speaking (see Bull, 1973; Faw and Waller, 1976), pre-questions had a positive specific effect on achievement but failed to enhance a generalized learning set. On the other hand, postquestions had both a specific and general facilitative effect on learning. Furthermore, some aptitude by treatment interaction (ATI) work on various question types (Shavelson, Berliner, Ranitch and Loeding, 1974) and frequency (Koran and Koran, 1975) suggested that learners with different general abilities react differentially to inserted mathemagenic questions. These and other mathemagenic

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findings have been critically analyzed in regards to the production of science instructional materials (see Wilson and Koran, 1976).

Faw and Waller (1976) reviewed mathemagenic-question studies and recommended future investigations focus more attention on the differential learning effects of school-relevant questions, texts and tests. Recent mathemagenic studies have been limited to evaluating ways of facilitating learning sets while reading a text. Techniques used by these investigators included restricting learners from reviewing relevant portions of the text when answering questions inserted periodically throughout a passage. Findings from these popular studies have greatly contributed to our understanding about ways of facilitating learning sets using various question types under a variety of conditions (Wilson and Koran, 1976). Faw and Waller (1976) recommend that future studies permit students to review reading passages for answers to study questions, evaluate behaviors requiring meaningful comprehension and examine how students with different learning abilities respond to varying question types.

It was hypothesized that students who are low verbal performers and who are given a science text will outperform those students who are also low verbal performers and who are given the same text with adjunct verbatim questions. Students who are high verbal performers will not be differentially effected by either instructional treatment. The present study was primarily part of a visual-verbal series (see Holliday, 1976a;Holliday, Brunner and Donais, 1977) of aptitude treatment interaction (ATI) investigations in science education - here, concerned with identifying a learner characteristic (verbal ability) indicative of optimal instructional methods (text plus adjunct verbatim

or no questions) in terms of comprehension (visual concept attainment) under classroom conditions.

Cronbach and Snow (1977) reviewed aptitude treatment interaction (ATI) studies dealing with adjunct questions and other instructive techniques (e.g., underlining, note taking) and concluded that these so-called facilitative methods were in many instances disruptive and counterproductive because they interferred with learners' usual ways of processing textual information. For example, Rothkopf (1972), using geology content concluded, that high school students of low ability effectively used mathemagenic questions while high ability students were not influenced by such support systems. On the other hand, Sanders (1973) reported an opposite effect, albeit under controversial experimental conditions. Subsequently, Shavelson, Berliner, Ranitch and Loeding (1974) found that higher order questions were helpful to low ability students and disruptive to high ability students yet these latter students were not affected by lower order questions presented with the text. Later, Shavelson, Berliner, Loeding and Stanton (1974) surprisingly discovered that a control text group generated higher mean scores than did mathemagenic higher order, lower order and shaping (a diminished cuing technique) questions. Faw and Waller (1976) suggested that ATI research findings dealing with questions adjunct to texts were inconclusive and inconsistent, and recommended more precise experimentation under more realistic conditions.

Accordingly, the purpose of this study was to investigate the differential effects on low and high verbal students of a specific questions type, that is, verbatim study questions adjunct to a text describing science concepts. Such easy-to-develop questions are found in some programmed learning materials and

are more often administered by teachers to low verbal students because these learners are sometimes perceived as being unable to answer "higher-order" questions. Yet, Samuels (1967) found that low verbal students are less likely to learn when given instructional support materials (e.g., adjunct pictures) containing "redundant" information and requiring little processing effort - that are adjunct to textual material clearly requiring more effort. He reasoned that such materials can distract this learner type from processing a text in a meaningful fashion.

Anderson and Faust (1967) concluded from a programmed instructional experiment on Russian vocabulary that students provided with a verbatim question correspondingly derived from an adjacent text learned comparatively more information when answers to the questions were not underlined in the programmed text. They reasoned that the no-underlined version at least required the students to search in a sufficient orthographic (perceptual) fashion to locate the answer in the text, whereas the underlined version merely required students to write the underlined word in the question blank (Anderson, 1967, 1970). Anderson (1972) suggested that instructional materials requiring students to attend and process in a more complete fashion than in either such programmed versions further increases the chances of semantic encoding in a learner's mind resulting in higher scores on a comprehension posttest.

Of secondary importance, it was hypothesized that students given either the text and questions or just the text will substantially outperform the control group. This second hypothesis is based on a visual comprehension study (Holliday and Thursby, 1977) which supported the use of a text as one successful means of describing visual concepts. Apparently little research

work has focused attention on the instructional effectiveness of a text in terms of classifying visual examples of verbally described concepts, a potentially useful technique in applied research experiments and in science classroom instruction.

Method

Sample. The sample consisted of 217 eighth grade earth science students enrolled in twelve Calgary (Alberta, Canada) public schools.

Materials. Materials developed for this study included an introduction to the experiment, a textual description of five fossil categories (ammonites, brachiopods, gastropods, pelecypods, and trilobites), 20 study questions, and a placebo passage designed for the control group.

The introduction of the experiment to all students consisted of a three-sentence advanced organizer describing the nature of fossils, a seven-sentence description of the posttest item to be administered upon everyone's completion of the instructional materials and an oral statement concerning the importance of the exercise. Here, students were told that their scores on the posttest would be sent to their science teacher and used in the calculation of course grades. Such a motivational incentive likely induces students to generate higher posttest scores (Faust, 1967) and more closely simulates a classroom situation typically experienced by these students.

The 538-word textual description of the fossils was presented in five separate sections on a single sheet of 21.5 x 35.5 cm. paper. At the top of each section the fossil name and its written pronounciation were printed in capital letters and underlined. Below each fossil name a physical description was printed in "simple" language repeating the fossil name often and using

descriptive adjectives and familiar analogies. For example, ammonites were analogously described as appearing "like a coiled electric burner...a snake or a rope coiled around and around lying flat on the ground...shape like a pancake".

The 20 study questions consisted of word-for-word statements derived from the text. In each case the fossil name and part of its physical description had been syntactically integrated into the selected sentences. Four statements were selected from each fossil description and one of two key or substantive words (never a fossil name) were deleted forming fill-in-the-blank questions. Questions containing two blanks were separated from each other by intervening word(s), so that the deleted words were never physically adjacent to one another. The question groups were given these 20 questions and asked to supply the (28) missing words.

The instrument used in this study was the popular vocabulary test (V-2) from the Kit of Reference Tests for Cognitive Factors (French, Ekstrom and Price, 1965). This aptitude measure purports to have a high loading on a single factor identified as a learner's general ability to understand the English language. This factor has also been reported in at least 70 published studies according to French et al. Furthermore, tests from this Kit measuring this factor and used in instructional research studies generally yield positive correlations with achievement measures (Shavelson, Berliner, Ranitch and Loeding, 1974).

The achievement test consisted of a visual concept posttest requiring students to identify 40 fossil specimens administered to the students in a stratified random fashion. Specifically, three fossil sets of 40 specimens each constituted the fossil criterion pool used in this study. The three

fossil sets were randomly assigned to the twelve participating classes. Therefore, these 120 specimens (24 specimens of each fossil category) provided a wide range of specimen variability. As a result of this large item pool, there was less chance that students would respond to unique specimen characteristics such as a misleading structural attribute. Furthermore, the generalizability of visual concept comprehension was increased by using a large varied specimen pool.

The students were provided with 40 numbered posttest items each stating, "The name of this fossil is: A) ammonite, B) brachiopod, C) gastropod, D) pelecypod, and E) trilobite". The students were instructed to examine each numbered specimen and then mark the correct response on their answer sheet.

The described posttest required those students (unfamiliar with the five visual concepts) to comprehend (semantically encode) the instructional description of the fossils, according to Anderson's (1972) discussion on guidelines for constructing comprehension test items. This unfamiliarity assumption or base-line performance level in this study was evaluated using a placebo text in the control group as recommended by Faw and Waller (1976).

Procedure

Students were administered the verbal ability test prior to the presentation of the instructional treatments. Subsequently, the 208 students were randomly assigned to one of three treatments: 1) text plus 20 study questions, 2) text plus no study questions, and 3) placebo passage.

Later, students were administered the posttest at one time. The 40 fossil specimens were placed in individually numbered containers. Each student

was presented with one fossil specimen at the beginning of the test. The students were then instructed to pass their specimens to adjacent students in a prescribed order at the end of a reasonable amount of time (about 45 seconds inspection intervals).

Results.

As predicted, students who were low verbal performers and who were provided with the text and no study question scored significantly higher on the posttest (Cronbach's alpha r = .95), than those low verbal learners provided with the text and study questions, $F = 8.14$, $df = 2/135$, $p < .01$. High verbal performers predictably were not differentially effected. Regression analysis was used to evaluate this ordinal interaction hypothesis as recommended by Cronbach and Snow (1969, 1977). A test for interaction in terms of the V-2 test scores (r = .66) and their experimental group memberships resulted in the expected ordinal interaction as illustrated in Figure I. The regression coefficient for the text with no-question treatment (n = 70) was .52 for the slope and the Y intercept was 22.55. The regression coefficient for the text plus verbatim question treatment (n = 68) was .66 for the slope and the Y intercept was 18.54. In addition the means and standard deviations are reported in Table I for the aptitude and achievement tests as prescribed by Cronbach and Snow (1977).

Of secondary importance, the control group scores (n = 70) were substantially lower than either other treatment group scores as shown in Table I.

Discussion.

Scores from the verbal ability and comprehension tests interacted producing nonparallel positive slopes and supporting the ATI ordinal hypothesis.

These results suggested that providing students of lower verbal ability with a science text is more helpful than providing them with the same text and verbatim study questions. In contrast, students of higher verbal ability seemed less effected by such adjunct questions. In general, lower verbal students ironically are more likely to be given verbatim questions because these low verbal (nonacademic) learners usually are perceived by teachers as needing remedial help of a highly simple nature. The problem with verbatim questions such as those found in some programmed learning and other materials (Anderson and Faust, 1967) is that comprehension or semantic encoding of the textual information is not requisite to the answering of this question type. Yet, the semantic encoding of the text in this study was prerequisite to the posttest task as suggested by the comparative low scores (almost at the chance level) generated by the control group. That is, students had to bring to mind meaningful representations of the five fossil concepts before visually identifying and discriminating the 40 fossil specimens used in the test. According to Anderson (1972), getting children to encode information in a semantic fashion is a central goal of school learning. Yet, students provided with verbatim questions adjunct to the text needed only to coordinate (rather than semantically encode) the "surface information" in the text to answer the questions according to Anderson's (1972) description of such tasks. Such coordination never ensures learner comprehension. The low verbal students given the questions and text perhaps thought that merely copying an answer from the text to the blanks provided on the question sheets constituted an adequate method of preparing for the posttest. High verbal students are probably less susceptable to the potentially dysfunctional effects

of verbatim questions and other external prompts requiring no semantic encoding as suggested by Samuel's (1967) study. Furthermore, these academically inclined students are ordinarily successful in comprehending verbal information under a variety of conditions, providing it is presented in a reasonable fashion (Holliday, Brunner and Donais, 1977).

This study did not prove that verbatim questions are dysfunctional to low verbal students. There exists many alternative combinations of variables such as the information content and presentation of the treatments and questions, the evaluated learning behaviors, and the instructional environment and general circumstances surrounding such a study. However, it is reasonable to assume that providing verbatim study questions adjunct to a text can be a counterproductive learning experience particularly for lower verbal students and that such classroom practices should be carefully monitored for those disruptive effects described in this study.

Faw and Waller (1976) argued that "major gaps exist and research efforts are most urgently needed" in the area of differential learning (ATI) effects of school-relevant questions. The present study has focused attention on a specific hypothesis within this domain and has simulated related work in mathematics education. Dr. J. Threadgill at the University of Calgary is currently re-evaluating the described ATI hypothesis and is also evaluating a main-effects hypothesis concerning the general effectiveness of simple study questions requiring comprehension. Analysis of her pilot data is encouraging. The final test results promises to make an even greater contribution to our understanding of school-relevant study questions.

Secondarily, the two treatment groups clearly outperformed the control

group and provided ample evidence of visual comprehension from verbal instruction. In fact, it is well documented that textual descriptions of concepts can facilitate comprehension under numerous verbal conditions (see Anderson and Kulhany, 1972; Markle, 1975). However, visual testing conditions have not been evaluated in this regard except in the present study and in one other instructional study. More specifically, Holliday and Thursby (1977) found that textual description of four architects' building styles was an effective instructional medium in terms of a posttest task requiring high school students to classify projected photographic examples of 44 existing buildings. This latter work and the present study support the facilitative effects of a text under separate conditions as measured by a visual concept comprehension task. Of course, no one is recommending at this time the sole use of textual materials to teach visual concepts under any classroom condition. Yet, the actual classroom use of verbal-visual presentations apparently ranks in second place behind verbal presentations without pictures because of the inflated value teachers, parents and students tend to assign to the printed word (Fleming, 1962; Holliday, 1973) and because of the perceived difficulty with which appropriate pictorial materials are available to most teachers (Holliday, 1976 b).

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TABLE I

OBSERVED MEANS AND STANDARD DEVIATIONS

FOR THE THREE GROUPS

Groups	V-2 test		Achievement test	
	$\bar{X}$	S.D.	$\bar{X}$	S.D.
text only	13.32	(4.72)	29.44	(8.06)
text and questions	12.09	(4.19)	26.51	(9.29)
Placebo text	12.73	(4.56)	10.43	(5.73)

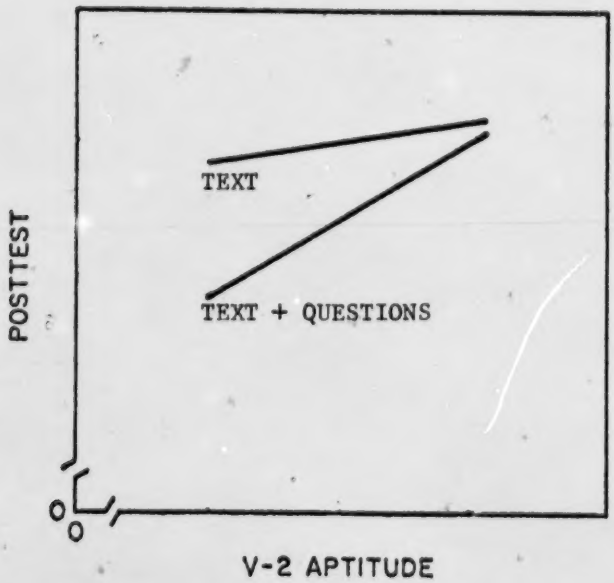

Fig I. Ordinal Interaction Illustrating Regression Slopes for the Two Treatments

AMMONITE (AM-MŌ-NĪTE)

An ammonite fossil has a coiled shell just like a coiled electric burner on an electric kitchen stove. In other words, an ammonite fossil usually looks like a snake or a rope coiled around and around lying flat on the ground. An ammonite fossil has a more or less flat shape like a pancake. Ammonite shells can have big or small coils and can be different colours.

BRACHIOPOD (BRA CHI O POD)

A brachiopod shell has the same shape as very thick butterfly or moth wings. This does not mean that a brachiopod shell has real wings. It means that the shape or outline of a brachiopod shell has the appearance of very thick butterfly wings.

There is one other thing you can do to recognize a brachiopod fossil. This is very important. First, if you think you have found a brachiopod, look at its flatest side. You must only look at the flatest side. Second, to recognize a brachiopod fossil, turn the fossil until one of its wings is on your left and the other wing is on your right. Third, make believe you cut through the centre of the fossil from top to bottom. The cut must be from top to bottom. If you did this, the fossil would be in two parts. If it is a brachiopod, the right part of the fossil will be the same shape as the left part of the fossil. In summary, when you cut through the centre of a brachiopod fossil from top to bottom, the right part of the fossil will be the same shape as the left part of the fossil. These three steps are very important.

A brachiopod is hard to tell from a pelecypod. Make sure you learn the three steps above. Otherwise, you may not be able to tell the difference between a brachiopod and a pelecypod.

GASTROPOD (GAS-TRO-POD)

A gastropod or snail shell looks like the ice cream in a Dairy Queen ice cream cone. The large rings of ice cream are on the bottom and the small rings of ice cream are on the top. In other words, a gastropod fossil has larger rings on the bottom and smaller rings on the top. Some gastropods have only 3 or 4 rings, others have many rings. The ring at the top of the gastropod is so small that the fossil comes to a point. This is just like the top or peak on a Dairy Queen ice cream cone.

PELECYPOD (P-LESS-A-POD)

When a pelecypod or clam is alive, it has two shells which fit tightly together. However, sometimes only one fossil shell can be seen or found. In other words, the top shell has been separated and lost from the bottom shell.

There are two very important things you have to know to recognize a pelecypod shell. You must look at only one shell of a pelecypod. Even if a pelecypod fossil has two shells, only look at one shell. In other words, put the pelecypod fossil in a position so that you can only see one shell. Next, with one straight cut, you can not divide one pelecypod shell into two equal parts. In other words, if you cut one pelecypod shell into two parts, one part will always be a different shape from the other part. It does not matter where you try to cut the one shell, the pelecypod shell can not be divided into two equal parts.

Make sure you learn that one pelecypod shell can not be cut into two equal parts with one straight cut. If you do not learn this, you may not be able to tell the difference between a pelecypod and a brachiopod.

TRILOBITE (TRĪ-LOW-BĪTE)

A trilobite fossil looks a little like some insects. A trilobite fossil has a head, body, and tail. Sometimes only one of these parts (the head, body or tail) can be seen in the fossil. A trilobite has many lines which run across the body and tail of the fossil. Trilobites can be big or small and can be different colours (for example gray or brown).

1. An ammonite fossil has a _____ shell just like a coiled electric _____ on an electric kitchen stove.

2. An ammonite fossil usually looks like a _____ or a _____ coiled around and around lying flat on the ground.

3. An ammonite fossil has a more or less _____ shape like a _____.

4. Ammonite shells can have _____ or small coils and can be _____ colours.

5. A brachiopod shell has the same _____ as very _____ butterfly or moth wings.

6. If you think you have found a brachiopod, _____ at its _____ side.

7. To recognize a brachiopod fossil, turn the fossil until one of its wings is on your _____ and the other wing is on your _____.

8. When you cut through the centre of a brachiopod fossil from top to bottom, the _____ part of the fossil will be the same shape as the _____ part of the fossil.

9. A gastropod or snail shell looks like the _____ in a Dairy Queen ice cream _____

10. A gastropod fossil has _____ rings on the bottom and _____ rings on the top.

11. Some gastropods have only 3 or _____ rings, others have _____ rings.

12. The ring at the top of the gastropod is so _____ that the fossil comes to a _____

13. When a pelecypod or _____ is alive, it has _____ shells which fit tightly together.

14. Even if a pelecypod fossil has two _____ only look at _____ shell.

15. With one straight cut, you can _____ divide one pelecypod shell into two _____ parts.

16. If you cut one pelecypod shell into two parts, one part will _____ be a _____ shape from the other part.

17. A trilobite fossil looks a _____ like some _____.

18. A trilobite fossil has a head, _____, and _____.

19. A trilobite fossil has many _____ which run _____ the body and tail of the fossil

20. Trilobites can be _____ or _____ and can be different colours (for example gray or brown).

Multiple regression analysis is a method for studying the effects and magnitude of the effects of more than one independent variable (Kerlinger, 1973). In this case, IQ scores (continuous variable) and the instructional treatments (discrete variable) constitute the independent variables.

(full model)

$$Y_1 = a_0 U + a_1 X_1 + a_2 X_2 + a_3 X_3 + a_4 X_4 + E_5$$

where:
a = regression constant
U = the unit vector
Y_1 = criterion vector
X_1 = 1 if the score on Y_1 comes from a member taught using the text plus drawing; zero otherwise
X_2 = 1 if the score on Y_1 comes from a member taught using the text; zero otherwise
X_3 = IQ score if the corresponding score on Y_1 comes from the group taught using the text plus drawing; zero otherwise.
X_4 = IQ score if the corresponding score on Y_1 comes from the group taught using the text; zero otherwise.
X_5 = sum of errors squared.

This equation will allow the regression lines of best fit to take a non-parallel form. The restricted equation describe below will force the two treatment lines to be parallel.

(intermediate equation)

$$Y_1 = a_0 U + a_1 X_1 + a_2 X_2 + a_5 X_5 + a_5 X_5 + E_6$$

Where all variables are identical with those in the full model and

$$a_5 = a_3 = a_4$$

If the two vectors X_3 and X_4 are added, we get a continuous vector whose elements are the IQ scores irrespective of group membership.

Therefore we can reduce the intermediate equation to

(restricted model)

$$Y_1 = a_0 U + a_1 X_1 + a_2 X_2 + a_5 Z_1 + E$$

Where Z_1 = the sum of vectors X_3 and X_4, or a continuous vector whose elements are IQ scores regardless of group membership.

a_5 = partial regression weight indicating slope.

The question is "does the constant difference between the regression lines equal zero? Or, "does the full ATI model significantly reduce the least error squares (E) relative to the restricted model?"

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